Army Corrosion Summit 2010, Huntsville

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Replacement for Cadmium Plating and Hexavalent Chromium on Fasteners and Electrical Connectors

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Outline

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Objective

- Replace cadmium plating and hexavalent chromium post treatment with high purity aluminum and tri-valent chromium conversion coating
- The intention is to make high purity aluminum the default replacement for fasteners and electrical shell connectors currently plated with cadmium, where technically permissible.

Guidance

- Office of the Secretary of Defense Directive
  - "Approve the use of alternatives [to ***hexavalent chromium***] where they can perform adequately for the intended application and operating environment."
- 29 CFR 1910.1200
  - Asbestos, beryllium, radioactive materials, ***hexavalent chromium***, (electroplating and coatings), ***cadmium*** (electroplating), mercury, or other highly toxic or carcinogenic materials
- European Union (EU) RoHS and REACH legislation restricts or bans many hazardous materials including hexavalent chromium, cadmium, and lead. Currently, the legislation does apply to the Military.

Background

- Advantages of Cadmium
  - It works
  - Applies to majority of materials and uses
  - Cheap and available

- Disadvantages
  - Chromium and cadmium are carcinogens
  - DoD directives to eliminate both

Background - Alternative Choices

- Numerous alternatives
  - Zinc nickel (Zn/Ni)
  - Tin zinc (Sn/Zn)
  - Zinc (Zn)
  - Aluminum (Al)
- Commercially Organic Coatings (e.g.)
  - Magni
  - Elisha
  - Geomet
  - Xylon

Background (Cont'd)

Numerous coating choices may seem attractive; however…

- Creates complexity for design, maintenance, & supply
- No configuration control
- No comprehensive knowledge of new galvanic couples introduced in joint designs
- Potential torque conflicts
- Hardness of mating surfaces
- Example: A joint released with a Zn-rich inorganic coated (Geomet) bolt, a Zn-Ni washer, and a Ni coated nut, mated to an aluminum substrate, would result in a galvanic corrosion issue.

Background

- The *good news* is that we have many choices
  - Competition
  - Availability

- The *bad news* is that we have many choices
  - Material compatibility
  - Logistics tail
    - Compatibility with legacy systems such as existing halves of cadmium plated connectors

Technical Aluminum vs. Cadmium Plating

- Aluminum Corrosion Performance –equivalent at same thickness
- Heat Resistance – Trivalent Chrome protects up to about 400 °F; Hexavalent Chrome fails at about 140 °F.
- Lubricity and Clamping is equivalent with friction modifier
- Galling – low risk with friction modifiers
- Volume of aluminum corrosion product increases, but not significantly vs cadmium

Technical - Why aluminum?
Galvanic series

Noble / Cathodic

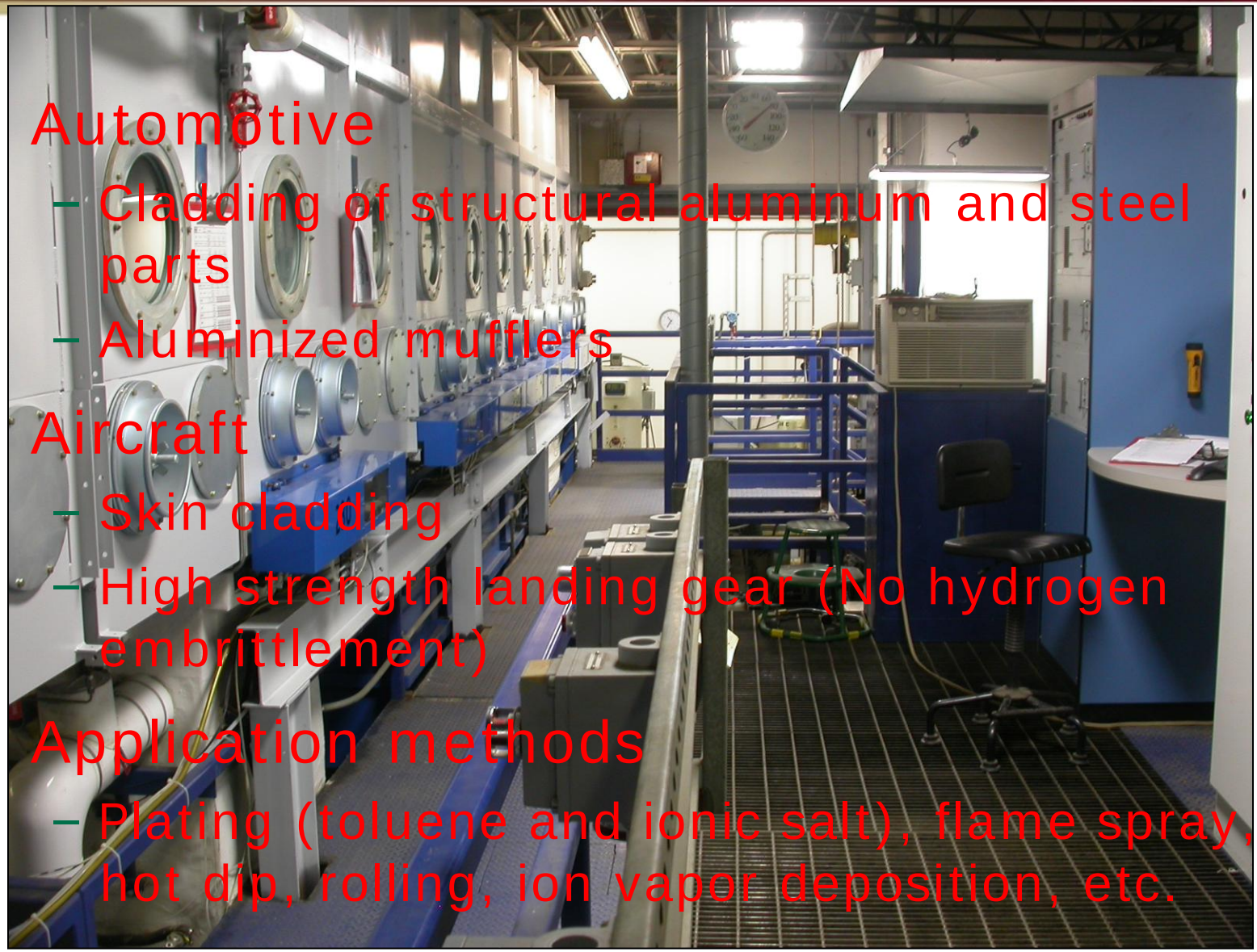
- Platinum
- Gold
- Graphite
- Titanium
- Silver
- 18-8Mo stainless steel (passive)
- 18-8 stainless steel (passive)
- Chromium stainless steel 11–30% Cr (passive)
- Inconel (passive) (80Ni-13Cr-7Fe)
- Nickel (passive)
- Silver solder
- Monel (70Ni-30Cu)
- Cupronickels (60–90Cu, 40-10Ni)
- Bronzes (Cu-Sn)
- Copper
- Brasses (Cu-Zn)
- Inconel (active)
- Nickel (active)
- Tin
- Lead
- Lead-tin solders
- 18-8Mo stainless steel (active)
- 18-8 stainless steel (active)
- Ni-Resist (high-nickel cast iron)
- Chromium stainless steel, 13% Cr (active)
- Cast iron
- Steel or iron
- Aluminum alloy 2024
- **Cadmium**
- Aluminum alloy 1100
- **Aluminum (high purity)**
- Zinc
- Magnesium and magnesium alloys

Active / Anodic

Technical - Plating Equipment / Process Comparison

	Cadmium	Aluminum
Plating Tanks	Standard	Standard
Anode	Standard	Standard
Tooling	Standard	Standard
Rectifier	Standard	Standard
Gantry	Standard	Standard
Plating Method	Rack or Barrel	Rack or Barrel
Bath Chemistry	HAZMAT Restricted	HAZMAT Restricted
Bath Chemistry	Aqueous Based	Non-aqueous
Hydrogen Embrittlement	Yes - Coated parts require 23+ hr bake at about 400 °F	No - No post-bake needed
Waste Stream Disposal	HAZMAT Landfill	Non-HAZMAT Blended Fuels
Plating Line Enclosure	No	Yes - plus nitrogen blanket to keep air & moisture out

Technical - Applications of High Purity Aluminum



- Automotive
  - Cladding of structural aluminum and steel parts
  - Aluminized mufflers
- Aircraft
  - Skin cladding
  - High strength landing gear (No hydrogen embrittlement)
- Application methods
  - Plating (toluene and ionic salt), flame spray, hot dip, rolling, ion vapor deposition, etc.

Coordination

- TARDEC has received comments and questions from
  - Government
    - DLA
      - DSCC has not concurred with this initiative
    - US Navy
    - US Air Force
    - ASETS Defense 09
  - Industry
    - Aviation industry
      - Boeing, Pratt & Whitney, Lockheed
    - Fastener manufacturers
    - Ground Equipment OEMs
    - Electrical connector OEM
    - SAE

Coordination (Cont)

- Contract let with US2 Inc. for Business case/future costs and availability analysis
- Received list of 10 interested suppliers from survey performed by Automation Alley in Michigan who are interested in application of high purity aluminum coatings.

Technical and Business Feedback

- Why all DoD
- Aircraft community comments/perspective on introduction of different products/coating
- Business questions
- Technical questions

Business/Logistics Questions

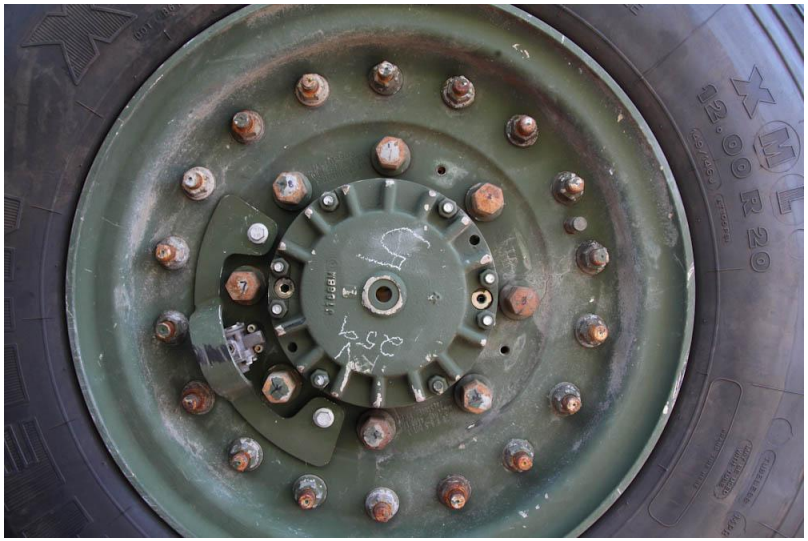
- *Cost*
  - *Implementation*
  - *Life Cycle cost*
    - *Procurement, Maintenance, Tracking of HAZMAT, Disposal/DEMIL*
- Availability
- Producibility
- Industrial supply base
- Capacity
  - Present, Future, Ramp up time
- Demand creation
- Competition

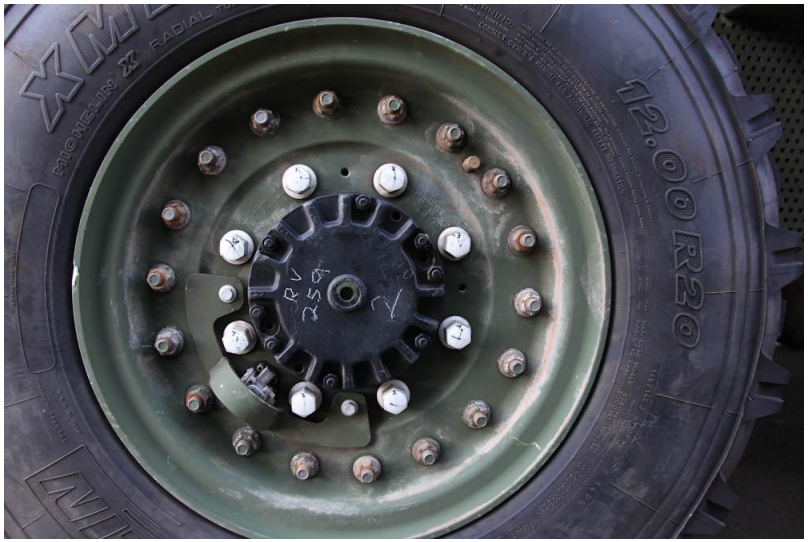
Technical Questions

- Corrosion/persistency of coating
- Galling
- Adequacy of testing
- Lubricant compatibility
- Processing
- Conductivity
- Aerospace requirements
- Rework and availability of alternatives
- Exposure to toluene in plating process

Test Update

- CTC Fastener study
  - Corrosion, lubricity, mechanical coupling and decoupling
- RESET program
  - Installed aluminum wheel studs on Stryker vehicles, inspected after 7 months in Hawaii





Future testing & development

- Quantify effects of Tri Chrome thickness on lubricity, wear resistance and corrosion
- Future development
  - Engineer combined durable and lubricious coating for large shell connector coupling and decoupling similar to current cadmium performance

Path Forward

- TARDEC continues to staff a DoD policy to the Office of the Secretary of Defense through the Army Corrosion Executive for the replacement of cadmium plated fasteners and electrical connectors with high-purity aluminum
- Need to evaluate present test methods with regard to material qualification
- Based on above study, need to re-evaluate test method in current MIL-Stds.
  - E.g., salt spray vs. cyclic corrosion testing, and outdoor exposure to correlate to field conditions and use

Questions and Discussion